

Artificial neural network based technique for energy management prediction

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ABSTRACT

The energy management of electrical machine is significant to ensure efficient power consumption. Mismanagement of energy consumption could give impact on low efficiency of energy consumption that leads to power wastage. This paper presents analysis of power consumption and electricity costing of the electrical machineries and equipment in High Voltage (HV) and Electrical Machine (EM) Laboratories at Faculty of Electrical Engineering (FKE), Universiti Teknologi MARA (UiTM) Shah Alam, Selangor, Malaysia. The electrical data are collected using Fluke Meter 1750. Based on the analysis, it is found that the estimated annually electricity cost for HV Laboratory and EM Laboratory are RM 392.00 and RM 3197.76 respectively. For prediction of energy consumption of the two laboratories, Artificial Neural Network (ANN) algorithm is applied as computational tool using feedforward network type. The results show that the ANN is successfully modelled to predict the energy consumption.

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1. INTRODUCTION

Commercial building is known as high consumption electrical energy due to large capacity of electrical equipment and resources [1-3]. Hence, energy management is crucial to ensure high efficiency of power consumption [2]. In Malaysia, based on the Efficient Management of Electrical Energy Regulations 2008 that was introduced on 15 December 2008, the management of large commercial and industrial electrical consumer are required to develop and carry out the energy efficient measures in order to improve the utilization and efficiency of electrical energy in this organization [3]. Besides this, power planning is crucial for cost efficiency of power generation of an area; in which power forecasting plays essential part of energy management.

Numerous research in energy management had been performed. Part of energy management, that is energy audit were performed at public and commercial buildings. The results and recommendation from the audit could improve the energy efficiency. This led to increase of production efficiency, improve product quality and reduce the production cost [4-8]. Studies in energy management for the industries dealt with heavy machineries were also conducted. It was found that with right size of space to placed heavy machineries and resources among the important parameters contribute to the energy consumption. Change in usage patterns and occupant awareness could also affected the amount of energy of the premise. These led to huge opportunities towards energy saving and improved energy efficiency [5-8].

For old rewound/faulty motors machineries that consumed high power can be changed to the new one that equipped with energy efficient system [7-8]. A study in energy management for steel rolling plant had been conducted by replacing the induction motor with more energy efficient and rescheduling the loads. It had proven that the electricity bills were reduced which results to reducing of unnecessary power loss [9-12]. Energy conservation had been conducted to carried out the potentials of energy saving with implementation of separate metering, reduction in electricity using on peak hours and use demand controller [13-15]. It helps reduce the unneeded load and estimate out the production cost [10], [16-17]. By introducing right technique in saving electricity and implement power factor correction could also contribute to the opportunities of energy saving [18].

The introduction of ANN to model and predict energy consumption have been widely proposed. Investigations in estimation of the electricity consumption through Artificial Neural Network (ANN) method had been performed. The estimation and prediction were successfully implemented to predict electricity usage for daily and hourly consumption and also load forecasting [19]. Various ANN techniques were proposed and comparison were made to distinguish the best method. Amongst the popular techniques, is Learning levenberg-marquardt algorithm, was proposed as training algorithm. In this algorithm, the transfer function been used was tansig for hidden layer and purelin for output neurons.

ANN method also able to modeling energy consumption for random day and the next hours by using Boolean metering system [20-21]. The application of ANN has some advantages such as the following: the mapping function in neural network is very flexible and neural network have the ability of generalizing form a limit set of data points and giving a good result at new data points [22-23]. Feed forwardback propagation (FFBP) and the general regression neural network (GRNN) have been affirmed as two effective methods in modelling and prediction by previous researchers. These two models are employed for the prediction of PV output power and had shown their effectiveness compared to statistical and autoregression approaches [24-26].

Based on the findings from the previous work, an investigation is performed to investigate the energy consumption at the Faculty of Electrical Engineering (FKE), UiTM Shah Alam, Selangor, Malaysia. The High Voltage (HV) and Electrical Machine (EM) Laboratories are chosen due to the fact that these two laboratories placed heavy machineries and equipment. The laboratories are used for undergraduate students in running their experiments such as DC Machine, resistor load bank, inductor load bank and vacuum pump. Electrical data are collected using Fluke Meter 1750 and analysis are performed to determine the amount of energy consumed by the machineries. For prediction of energy consumption at both laboratories, Artificial Neural Network (ANN) using feedforward neural network type is applied. The prediction is usefull and can be further applied to other premised within the faculty for energy management.

2. RESEARCH METHOD

For the purpose of the project, two laboratories located at FKE, UiTM Shah Alam, Selangor are chosen, which are HV Laboratory (Block 4, 4th floor) and EM Laboratory (Block 4, 6th floor). The two laboratories are normally used for educational and experiment for the undergraduate engineering students. The HV Laboratory has two types of experiments and are performed on Monday and Friday weekly. While for the EM Laboratory, four different types of experiment are run from Tuesday until Friday weekly. Fluke Meter Power Quality Analyzer 1750. 1750 is used to collect the energy consumption for both laboratories. The data collected for both laboratories were taken from 18/10/2018 until 25/10/2018 during semester September 2018 – January 2019 session within one-week. All calculations are based on Tenaga Nasional Berhad (TNB) Tariff for commercial building; which is tariff C2 with current rates given RM0.365/kWh.

Artificial Neural Network (ANN) is developed for prediction of energy consumption. Using feedforward neural network type, the prediction is based on TRAINLM as training function, LEARNGDM as learning function, MSE as performance function and LOGSIG as transfer function. The input data are power consumption, number of experiment run, hours of experiment and electricity cost while the output data is energy consumption. For the development of the ANN, the input data are divided into 70/30 in terms of percentage of training and testing. The 70/30 ratio is to give the higher coefficient of correlation. The flowchart of the ANN development for the testing and traing are as shown in Figure 1(a) and 1(b) respectively.

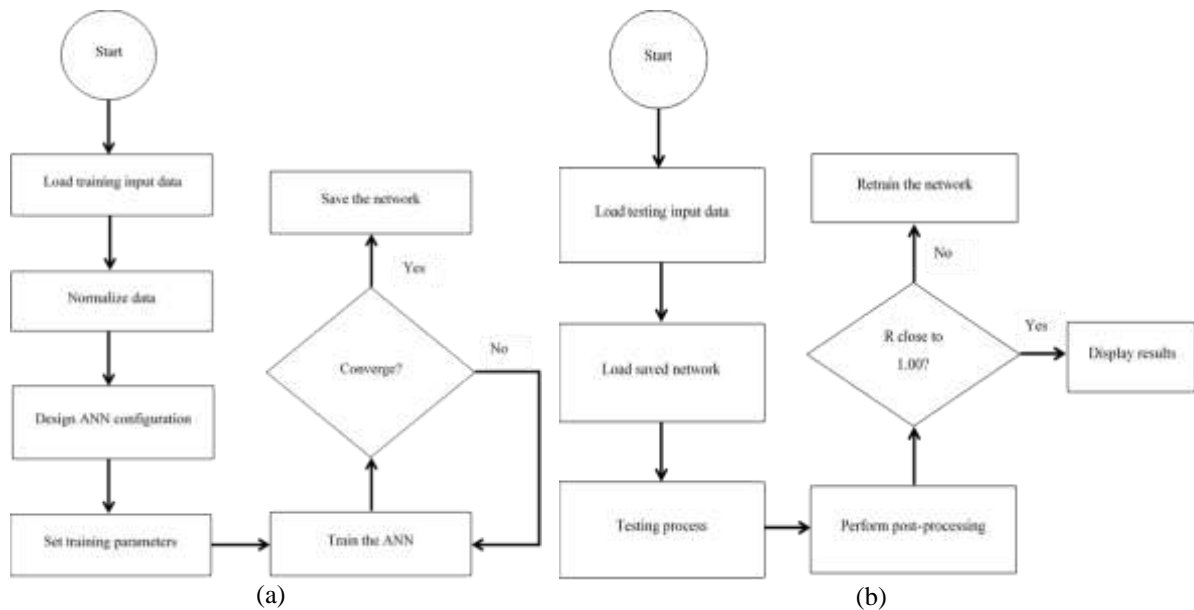


Figure 1. ANN Development (a) ANN Testing and, (b) Training workflow

3. RESULTS AND ANALYSIS

3.1. Energy Consumption

Table 1 shows the energy consumption for HV Laboratory taken from 18/10/2018 until 25/10/2018 in semester September 2018 – January 2019 session. It is found that the higher energy usage for HV Laboratory is 18.9 kWh on Friday. Based on the weekly data, prediction of energy consumption for monthly and annually are calculated. It is found that the total energy consumption for one week is 30.24 kWh, and monthly is 120.96 kWh. The monthly energy consumption is multiplied by four weeks since the same experiment with same equipment are conducted throughout the semester in every week. Based on this, total annually of energy consumption is predicted at 967.68 kWh. The total annually times by eight months because in one year there are two semesters which is September-January and July- Mac.

Table 1. Energy Consumption of HV Laboratory

TOTAL ENERGY CONSUMPTION (kWh)		
Data Collected	Monday	11.34 kWh
(Daily Basis)	Friday	18.90 kWh
Weekly(Calculated)	Total weekly = Sum of daily	
	Total weekly = 11.34 kWh + 18.90 kWh	
	Total weekly = 30.24 kWh	
	Total monthly = sum of weekly x 4 weeks	
	Total monthly = 30.24 kWh x 4 weeks	
	Total monthly = 120.96 kWh	
	Monthly(Predicted)	Total annually = sum of weekly x 8 months
	Annually(Predicted)	
Total annually = 120.96 kWh x 8 months		
Total annually = 967.68 kWh		
Semester: (Sept 2018 – Jan 2019) and (Mac 2019 – July 2019).		

Table 2 represents the calculation of EM Laboratory taken from 21/09/2018 until 28/09/2018 in semester September 2018 – January 2019 session. The higher energy consumption is 87.00 kWh which is on Tuesday whereby the experiment conducted using DC Generator and Balance Three Phase Circuit. Based on the observation, the DC Generator experiment consumed more energy consumption compared to Balance Three Phase Circuit experiment. This is because the equipment used to run DC Generator needs more power to operate the machine. Based on weekly data, prediction of energy consumption on monthly and annually are calculated. It is found that the total energy consumption for one week is 273.78 kWh and in monthly the EM experiments consumed 1095.12 kWh. The monthly energy consumption times four week because same experiment with same equipment are conducted weekly. The total annually of energy consumption is 8760.96

kWh. The total annually is multiplied with eight months because in one year there are two semesters which is September-January and July-March.

Table 2. Energy Consumption of EM Laboratory

		TOTAL ENERGY CONSUMPTION (kWh)
Data Collected (Daily Basis)	Tuesday	87.00 kWh
	Wednesday	68.04 kWh
	Thursday	63.66 kWh
	Friday	55.08 kWh
Weekly(Predicted)		Total weekly = sum of daily Total weekly = 87.00 kWh + 68.04 kWh + 63.66 kWh + 55.08 kWh Total weekly = 273.78 kWh
Monthly(Predicted)		Total monthly = sum of weekly x 4 weeks Total monthly = 273.8 kWh x 4 weeks Total monthly = 1095.12 kWh
Annually(Predicted)		Total annually = sum of monthly x 8 months Total annually = 1095.2 x 8 months Total annually = 8760.96 kWh

Table 3. Total Energy Consumption for Two Laboratories

	TOTAL ENERGY CONSUMPTION (kWh)
Weekly(Calculated)	30.24 kWh + 273.78 kWh = 304.02 kWh
Monthly(Predicted)	120.96 kWh + 1095.12 kWh = 1216.08 kWh
Annually(Predicted)	967.68 kWh + 8760.9 kWh = 9728.58 kWh

Based on Table 3, the energy consumption for both laboratories in weekly is calculated and the value is 304.02kWh. The total energy consumption for monthly for both laboratories is 1216.08 kWh while for annually is 9728.58 kWh. Based on these analysis, total weekly consumption of EM Laboratory consumes more energy consumption than HV Laboratory because EM Laboratory run four experiments in a week while HV Laboratory runs two experiments only.

3.2. Electricity Cost

The calculation for electricity costing is performed by using Tenaga Nasional Berhad (TNB) tariff. The tariff category is tariff C2 which is for medium voltage peak/off peak commercial tariff (all kWh during peak period), with current rates 36.5 sen/kWh.

a) High Voltage Laboratory

Table 4 shows the the electricity cost for HV Laboratory on Monday and Friday that consumed high energy when running the experiments. The calculated and predicted electricity cost are tabulated in Table 5. The electricity cost for one week is calculated at RM 11.04. The predicted amount is RM 44.16 pr month and RM 353.28 per annual. The electricity cost is low because it only measures on machine load, excluding the air conditioner, lighting and other loads. Moreover, the machine had been installed in single phase condition and only at red phase.

Table 4. Electricity Cost for HV Laboratory

DAY	DATE	ENERGY CONSUMPTION(kWh)	ELECTRICITY COST (RM)
Friday	19/10/2018	18.90	18.90 kWh x RM 0.365= RM 6.90
Monday	22/10/2018	11.34	11.34 kWh x RM 0.365= RM 4.14

Table 5. Total Electricity Cost for HV Laboratory Based on Weekly, Monthly and Annually

	TOTAL ELECTRICITY COST (RM)
Weekly(Calculated)	= Sum of daily
	= RM 6.90 + RM 4.14
	= RM 11.04
Monthly(Predicted)	= Sum of weekly x 4 weeks
	= RM 11.04 x 4 weeks
	= RM 44.16
Annually(Predicted)	= Sum of monthly x 8 months
	= RM 44.16 x 8 months
	= RM 353.28

Table 6 shows the daily electricity cost for EM Laboratory. It is found that on Tuesday, the laboratory consumed the highest energy consumption that contributed to highest electricity cost. The total electricity cost for one week is RM 99.93.

Table 6. Electricity Cost for EM Laboratory

DAY	DATE	ENERGY CONSUMPTION (kWh)	ELECTRICITY COST (RM)
Tuesday	25/09/2018	87.00	87.00 kWh x RM0.365 = RM 31.76
Wednesday	26/09/2018	68.04	68.04 kWh x RM0.365 = RM 24.83
Thursday	27/09/2018	63.66	63.66 kWh x RM0.365 = RM 23.24
Friday	28/09/2018	55.08	55.08 kWh x RM0.365 = RM 20.10

Table 7 tabulated the predicted monthly and annually electricity cost; which are RM 399.72 and RM 3197.76 respectively. It is found that, the electricity cost for EM Laboratory is higher compared to HV Laboratory because the number of experiments runs are four times per week in EM Laboratory, compared to HV Laboratory that runs only two times per week. Besides that, there are more machineries and equipment in the EM compared to HV laboratory.

Table 7. Total Electricity Cost for EM Laboratory Based on Weekly, Monthly and Annually

	Total Electricity Cost (RM)
Weekly(Calculated)	Sum of daily= RM 31.76 + RM 24.83 + RM 23.24 + RM 20.10= RM 99.93
Monthly(Predicted)	Sum of weekly x 4 months= RM 99.93 x 4 months= RM 399.72
Annually(Predicted)	Sum of monthly x 8 months= RM 399.72 x 8 months= RM 3197.76

3.3. Total Electricity Cost for Two Laboratories

Table 8 summarized the total amount of calculated and predicted electricity cost for both laboratories. The total calculated weekly electricity cost for both laboratories is RM 110.97. While the predicted electricity costs is RM 443.88 per month, that amounted to RM 3551.04 annually.

Table 8. Total Electricity Cost for Two Laboratories

	Total Electricity Cost (RM)
Weekly(Calculated)	RM 11.04 + RM 99.93 = RM 110.97
Monthly(Predicted)	RM 44.16 + RM 399.72 = RM 443.88
Annually(Predicted)	RM 353.28 + RM 3197.76 = RM 3551.04

3.3.1. Prediction of Energy Consumption using Artificial Neural Network (ANN) Method

Finally, the prediction of the energy consumption for both laboratories is modelled using ANN algorithm. Refer to Figure 2(a), the prediction energy consumption on HV Laboratory shows value of correlation of training is found at $R=0.99984$ while testing is $R=0.99913$. MSE found in training set is $9.8837e-06$ at epoch 19. In Figure. 1(b), the prediction for EM Laboratory obtained value of correlation of training is $R=0.99994$ and testing is $R=0.99977$. MSE for training set found by algorithm is $9.8939e-06$ at epoch 29. Training performance for both laboratories are found converged. Therefore, the predictions of energy consumption for both laboratories are successfully achieved. Finally, this ANN method prediction can be applied by the Faculty of Electrical Engineering, UiTM Shah Alam in forecasting future energy consumption.

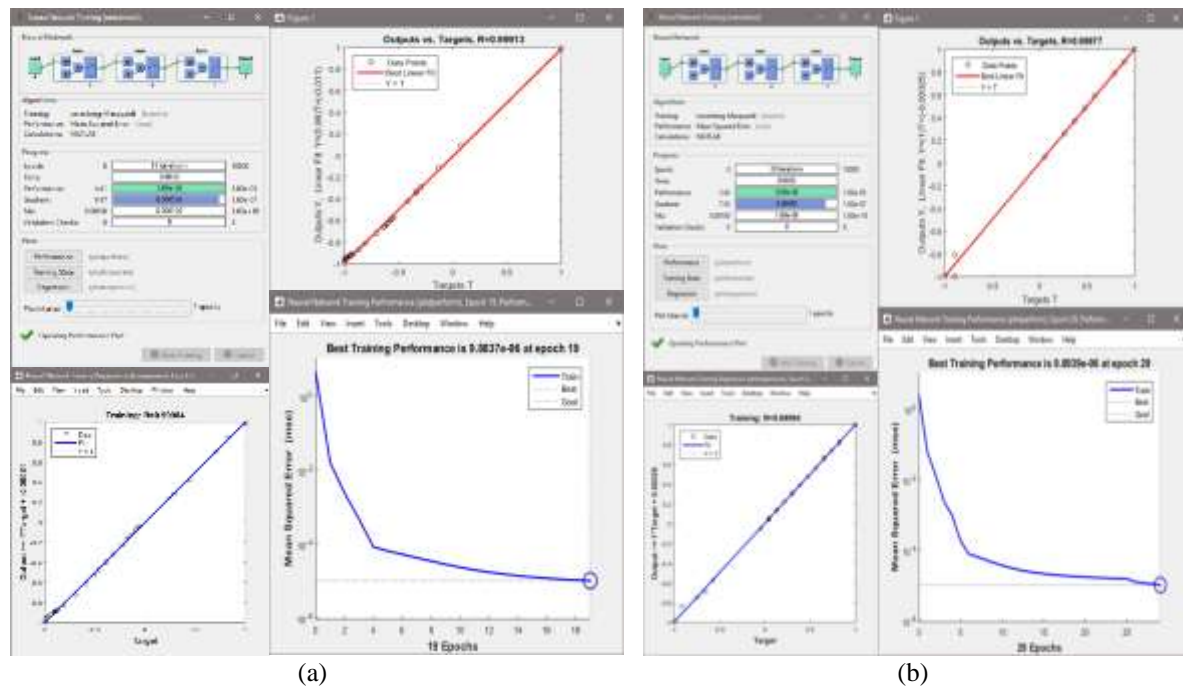


Figure 2. ANN prediction for (a) HV Laboratory, (b) EM Laboratory

4. CONCLUSION

The energy consumption and electricity costing for HV and EM Laboratories were successfully analyzed and presented. From this analysis, it was found that the total energy consumption of HV Laboratory is lower than EM Laboratory. The electricity cost for HV Laboratory was RM 392.00 per year while EM Laboratory RM 3197.76. For prediction of energy consumption, ANN was successfully simulated and tested. The ANN shows the best result prediction of energy consumption with $R=0.99913$ for HV Laboratory while EM Laboratory $R=0.99977$ with training results for both laboratories were found converged.

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